

Seeding Rates for Stale Seedbed Rice Production in the Midsouthern United States

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ABSTRACT

The establishment of an adequate and uniform rice (*Oryza sativa* L.) stand is critical to achieve high grain yields. The literature is extensive for older cultivars planted in conventional tillage and/or water-seeded systems; however, there are no published data for current cultivars grown in stale seedbed systems. Six of the cultivars most commonly grown in the Midsouth rice production area of the USA were drill seeded at densities of 108, 215, 323, 430, and 538 seeds m^{-2} into a stale seedbed at Crowley, LA, from 2002 to 2004, and in Clarksdale, MS, in 2003 and 2004. Established plant densities responded linearly to seeding rate for all cultivars except Cocodrie, which responded quadratically. Rough rice yields were not affected by seeding rate for Cheniere, but followed a quadratic relationship for the cultivars CL161, Cocodrie, and Priscilla. A location \times seeding rate interaction was detected for yield of Wells. Seeding rate did not affect rough rice yields for Wells in Mississippi, while in Louisiana, yields responded quadratically. Francis rough rice yields increased linearly with increased seeding rates. Optimal rough rice grain yields can be achieved in Mississippi and Louisiana with a seeding rate of 323 seeds m^{-2} for cultivars that are currently grown across the Midsouth rice-producing area in the USA. Furthermore, depending on the cultivar, when plant densities are uniform and range from 50 to 70 plants m^{-2} , the resulting rice grain yields may offset the cost of terminating the stand and replanting.

THE ESTABLISHMENT of an adequate and uniform rice stand is critical to achieve high grain yields. Various factors influence a producer's ability to obtain an optimum plant density. Seedbed conditions, soil temperature, depth and uniformity of planting, seed germination percentage, and seedling vigor interact to determine the final seedling population. After emergence, controlling diseases, weeds, insects, and birds, as well as having suitable growing conditions, ultimately affect the plant population from which grain is produced. Counce (1987) documented that the optimum plant density for non-semidwarf, U.S. rice cultivars grown in a drill-seeded, conventionally tilled cultural system in Arkansas was

130 to 172 plants m^{-2} with no significant rice grain yield differences with plant densities ranging from 172 to 430 plants m^{-2} . Optimum semidwarf rice plant populations were achieved on conventionally tilled histosols in Florida with seedling densities that ranged from 136 to 372 seedlings m^{-2} (Jones and Snyder, 1987). Miller et al. (1991) reported that rice grain yields in a continuously flooded, water-seeded cultural system were dependent on final tiller density, with rice grain yields increasing as final tiller density increased up to 700 tillers m^{-2} .

Most rice in the USA is grown using conventional tillage; however, conservation tillage has gained acceptance in many rice-growing areas (Street and Bollich, 2003) and is increasing in the Midsouth. The adoption of conservation tillage has been encouraged because of its economical and environmental benefits. Al-Kaisi and Yin (2004) reported that economic returns for no-till corn (*Zea mays* L.) production were equal or greater than economic returns for corn produced using conventional tillage. The no-till practice in rice reduced total solids and nutrients in rice field discharge water (Feagley et al., 1992; Bollich and Feagley, 1994). However, reduced tillage rice production is not without problems. Preplant vegetation management, difficulties in establishing stand, limited opportunity to apply fertilizer nutrients properly, and varieties that have performed poorly in no-till systems are factors that have limited the commercial use of no-till or other conservation tillage techniques for rice.

Conventional and reduced tillage are both applicable with the drill- and water-seeded cultural systems. Conventional tillage provides a uniform, weed-free seedbed that promotes seedling emergence and facilitates drainage following land leveling processes used to smooth the soil surface after tillage. Reduced tillage includes both no-tillage and stale seedbed systems (Linscombe et al., 1999; Slaton and Cartwright, 2001). Rice is planted into the residue of a previous crop in a no-till system, whereas in the stale seedbed system, previous crop residue is destroyed by tillage in the fall, and seedbeds remain fallow during the winter. Mild winter conditions allow native winter annual weeds to revegetate the fall-prepared seedbeds. By spring, winter weeds must be controlled either with tillage or burndown herbicides before seeding can be performed. In either of these production systems, producers can realize benefits by planting earlier than when a conventional tillage system is utilized.

Previous rice seeding rate research examined the response of cultivars that have now been replaced with higher-yielding cultivars (Counce, 1987; Gravois and Helms, 1992; Jones and Snyder, 1987; Miller et al., 1991). Furthermore, published literature on rice seeding rates was conducted either on conventionally tilled soil or in a water-seeded system. The response of current

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cultivars drill seeded into a stale seedbed has not been investigated. The development of herbicide-resistant (Clearfield¹) rice cultivars has added a new dimension to rice production in the Midsouth by providing an effective tool to control red rice (*Oryza sativa* L.) (Pellerin et al., 2004). Because herbicide-resistant rice seed are more expensive than seed of conventional cultivars, seeding rates with herbicide-resistant cultivars are very important to minimize production costs. Furthermore, adverse conditions—such as low air or soil temperatures or excessive rainfall following seeding—often exist in the production environment, inhibiting establishment of a uniform stand of adequate plant density. When this occurs, producers must decide either to terminate or intensively manage the existing stand. If producers understand the expected grain yields associated with low stand densities, they will be better equipped to make that management decision. Therefore, the objective of this research was to determine the effect of seeding rate on plant density and rough rice yield for rice cultivars currently grown in the Midsouth rice-producing area of the USA when seeded into a stale seedbed.

MATERIALS AND METHODS

Separate experiments to determine the plant density and rough rice yield response of six rice cultivars to different seeding rates were conducted in 2002, 2003, and 2004 at the Louisiana State University AgCenter Rice Research Station near Crowley, LA, and in 2003 and 2004 on a producer's field near Clarksdale, MS. The soil at Crowley was a Crowley silt loam (fine montmorillonitic, thermic Typic Albaqualfs) with a water pH of 6.8 and 1.8% organic matter. The soil at Clarksdale was an Alligator silty clay (very-fine, smectitic, thermic Chromic Dystraquerts) with a water pH of 6.5 and 2.2% organic matter.

The experimental sites used at Crowley were left fallow in alternating years whereas the sites at Clarksdale were in a 1:1 rotation with soybean [*Glycine max* (L.) Merr]. Field preparation each site year consisted of fall disking and two passes in opposite directions with a two-way bed conditioner equipped with rolling baskets and S-tine harrows set to operate at a 6-cm depth. Experimental sites were left fallow during the winter of each year. Emerged vegetation was controlled using glyphosate [*N*-(phosphonomethyl) glycine] at 840 g a.e. ha⁻¹ plus 2,4-D (2,4-dichlorophenoxyacetic acid) at 840 g a.i. ha⁻¹ 4 wk before seeding. Surface irrigation occurred immediately after seeding, at the two- to three-leaf rice stage, and at the three- to four-leaf rice stage at Crowley, whereas irrigation timing was at the two- to three-leaf rice stage at Clarksdale. The experimental sites were treated with fipronil [5-amino-1-(2,6-dichloro-4-(trifluoromethyl)phenyl)-4-((1*R*,*S*)-trifluoromethyl)sulfinyl)-1-*H*-pyrazole-3-carbonitrile] at 56 g a.i. ha⁻¹ before planting for control of rice water weevil (*Lissorhoptrus oryzophilus* Kuschel). Propanil [*N*-(3,4-dichlorophenyl)propanamide] at 3400 g a.i. ha⁻¹ plus molinate (*S*-ethyl hexahydro-1*H*-azepine-1-carbothioate) at 3400 g a.i. ha⁻¹ plus halosulfuron [3-chloro-5-[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]-amino]sulfonyl]-1-methyl-1*H*-pyrazole-4-carboxylic acid] at 53 g a.i. ha⁻¹ were applied 3 d before flood establishment to maintain weed-free plots at Crowley. Clomazone [2-(2-chlorophenyl)methyl-4,4-dimethyl-3-isoxazolidinone] at 560 g a.i. ha⁻¹ was applied immediately after planting at Clarksdale.

Thiobencarb {*S*-[(4-chlorophenyl)methyl]diethylcarbamothioate} at 4500 g a.i. ha⁻¹ plus halosulfuron at 12 g a.i. ha⁻¹ was applied 2 d before flood establishment. The flood was established when rice was at the four- to five-leaf stage at both locations. At Crowley, P and K were applied based on soil test results at a rate of 30 and 60 kg ha⁻¹, respectively, before tillage in the fall, while N was applied at the rate of 185 N kg ha⁻¹ as urea immediately before flood establishment. At Clarksdale, 24 kg N ha⁻¹ as ammonium sulfate was applied at the two- to three-leaf rice stage before irrigation. Before flood establishment, 155 kg N ha⁻¹ as urea was applied and followed by an additional 52 kg N ha⁻¹ as urea at panicle differentiation. Standard agronomic and pest management practices were used during the growing season (Linscombe et al., 1999; Miller and Street, 1999).

At Crowley, the long-grain rice cultivars Cocodrie, Francis, and Wells were tested in 2002, 2003, and 2004, and the long-grain cultivar Cheniere was tested in 2003 and 2004. These same four long-grain rice cultivars were tested in 2003 and 2004 at Clarksdale. Additionally, 'CL161' was evaluated at Crowley from 2002 to 2004, and 'Priscilla' was evaluated at Clarksdale in 2003 and 2004. The response of these cultivars to seeding rates was tested in separate experiments, but experiments were conducted concurrently. Rice was drill-seeded on 23 Mar. 2002, 15 Apr. 2003, and 24 Mar. 2004 at Crowley; and on 16 Apr. 2003 and 20 Apr. 2004 at Clarksdale. All experiments were drill-seeded using grain drills equipped with double-disk openers and press wheels with 18 cm between each row. At Crowley, experiments were drill-seeded with a small plot grain drill (Marliss Pasture King, Sukup Manufacturing Co., Sheffield, IA) equipped with belt cone-type seeders (Almaco, Nevada, IA). At Clarksdale, experiments were drill-seeded with a custom-made small plot grain drill equipped with Sunflower double-disk openers (Sunflower Manufacturing, Beloit, KS), and a cell-cone seeder (Kincaid Manufacturing, Haven, KS). Individual plots consisted of 12 rows measuring 7.6 m in length at Crowley, and seven rows measuring 5.2 m in length at Clarksdale.

The experimental design for all experiments was a randomized complete block with four replications. Treatments included seeding rates of 108, 215, 323, 430, and 538 seeds m⁻². In each year for each location, the average 1000-grain weight was determined from five random samples of each cultivar to determine seeds kg⁻¹ for each cultivar. Seed of each cultivar for individual plots were then packaged based on weight. Rice seeding rates of 334 to 430 seeds m⁻² are recommended in Louisiana and Mississippi to achieve optimum rice plant density at emergence of 161 to 215 plants m⁻² (Linscombe et al., 1999; Miller and Street, 1999). Seeding rates in these experiments were chosen to cover a range of seeding rates from 33% lower than the minimum recommended seeding rate to 25% higher than the maximum recommended seeding rate. Seed of each cultivar were treated with giberellic acid at 150 mg kg⁻¹ and mancozeb (ethylene bisdithiocarbamate) at 130 mg kg⁻¹.

The number of seedlings m⁻² were measured 10 to 14 d after seedling emergence by counting the main stems in the center two rows from an area 2.8 m in length in each plot at Crowley and by counting the main stems on the entire length of the center row of each plot at Clarksdale. Rice plots were harvested with small-plot combines, and rough rice yields were adjusted to 120 g kg⁻¹ moisture content.

Plant density and rough rice yield data were combined for analysis of variance (ANOVA) and tested for interactions among fixed effects using a mixed model approach (SAS Institute, 2003). Location and seeding rate were fixed effects. Year, replications, and any interactions with these factors were con-

¹ Clearfield is a registered trademark of BASF Corp., 3000 North Continental Drive, Mount Olive, NJ 07828-1234.

Table 1. Mean plant density, rough rice yield, and model parameters across locations and years for each seeding rate and cultivar.

Seeding rate	Plant density						Rough rice yield				
	Cocodrie	Cheniére	CL161	Francis	Priscilla	Wells	Cocodrie	Cheniére	CL161	Francis	Priscilla
seeds m ⁻²	plants m ⁻²						kg ha ⁻¹				
108	67	66	52	61	71	72	9 314	9336	7575	9 428	10 728
215	143	127	105	137	113	133	10 012	9676	8090	9 825	11 371
323	201	178	167	182	174	198	10 133	9593	8327	10 062	11 562
430	262	206	222	237	262	253	10 187	9787	8141	10 152	11 729
538	284	314	249	324	330	282	10 245	9516	8028	10 406	11 163
	*Q†	**L	**L	**L	**L	**L	*Q	NS	*Q	**L	*Q

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† Q, quadratic response; L, linear response.

sidered random effects as suggested by Carmer et al. (1989) and were included in the ANOVA so that broader inferences could be made concerning location and seeding rate effects. Each cultivar was analyzed separately. The slice option in SAS (SAS Institute, 2003) was used to determine the levels of the simple effects contributing to the interaction (Petersen, 1985). Treatment means were subjected to trend analysis and a significance level of 0.05 was used for the statistical tests.

RESULTS AND DISCUSSION

Researchers recommend the optimum rice plant density at emergence to be 161 to 215 plants m⁻² (Saichuk et al., 2005; Wilson et al., 2005). Plant densities within this suggested range were attained for all cultivars in the current research with a seeding rate of 323 seeds m⁻². Plant densities increased linearly with seeding rates for all cultivars except Cocodrie, which responded in a quadratic fashion (Table 1). Cocodrie, CL161, and Priscilla rough rice yields responded quadratically to seeding rate, and the largest increase in rough rice yield in response to seeding rate occurred when seeding rates for these three cultivars increased from 108 to 215 seeds m⁻² (Table 1). Rough rice yields increased by 7.5, 6.8, and 6.0% for Cocodrie, CL161, and Priscilla, respectively, when seeding rate increased from 108 to 215 seeds m⁻². The next incremental increase in seeding rate produced a 0.5, 2.8, and 1.7% rough rice yield increase for Cocodrie, CL161, and Priscilla, respectively. Rough rice yield of Francis increased linearly with seeding rate, reaching a maximum of 10 406 kg ha⁻¹ at a seeding rate of 538 seeds m⁻². However, lodging at Clarksdale increased with increasing seeding rate (data not shown), which has also been documented for other tall cultivars (Dofing and Knight, 1994). A location × seeding rate interaction was detected for rough rice yields of Wells. The source of the location × seeding rate interaction could not be determined. At Crowley,

rough rice yields responded quadratically to increasing seeding rate, but seeding rate did not affect rough rice yields for Wells at Clarksdale (Table 2). The highest rough rice yield for Wells was attained with the highest seeding rate; however, this yield was only 2.5% greater than the yield achieved with a seeding rate of 323 seeds m⁻². Seeding rate had no effect on rough rice yields of Wells at Clarksdale (Table 2), or Cheniere when averaged across the Louisiana and Mississippi locations (Table 1).

These data suggest that currently grown cultivars seeded in a stale seedbed respond to seeding rate similarly to older cultivars that were evaluated in conventional tillage and/or water-seeded systems (Counce, 1987; Jones and Snyder, 1987; Miller et al., 1991). Yield data presented here show the ability of rice to overcome suboptimal plant densities (Wells and Faw, 1978; Counce and Wells, 1990; Gravois and Helms, 1992; Wu et al., 1998). Additional N fertilizer applied during early vegetative growth can allow suboptimal rice plant densities to produce yields similar to those achieved with optimum plant densities (Counce et al., 1992). Rough rice yields decrease when rice is planted later than the optimum planting time (Slaton et al., 2003). If rice requires replanting at later than the optimum planting time, harvest can be delayed as much as 1 mo compared with an optimum planting time. Furthermore, in Louisiana, a ratoon-crop harvest (grain harvested from tillers originating on the stubble of a previously harvested crop) is valuable to a producer's income because it increases total production on a given area with a limited amount of additional input. A 1-mo delay in main-crop harvest may eliminate the opportunity to harvest a ratoon crop. Finally, as use of Clearfield¹ production technology increases, reducing seeding rates may be necessary to decrease the cost of planting certain cultivars.

CONCLUSION

Optimum rough rice yields can be achieved with a seeding rate of 323 seeds m⁻² for the currently grown cultivars in Louisiana and Mississippi using a stale-seedbed system. A seeding rate of 323 seeds m⁻² produced plant densities that ranged from 167 plants m⁻² for CL161 to 201 plants m⁻² for Cocodrie. Cheniere grain yields were not affected by seeding rate, as was true for Wells when grown in Mississippi (Table 1 and 2). Except for Wells grown in Louisiana, where a 16% yield in-

Table 2. Mean rough rice yields across years for Wells grown at Crowley, Louisiana, and Clarksdale, Mississippi.

Seeding rate	Crowley	Clarksdale
seeds m ⁻²	kg ha ⁻¹	
108	7034	10 953
215	7587	11 782
323	8136	11 762
430	8308	11 500
538	8345	11 601
	**Q†	NS

** Significant at the 0.01 probability level.

† Q, quadratic response.

crease was observed by increasing from the lowest (108 seeds m^{-2}) to the highest (538 seeds m^{-2}) seeding rate, these data suggest that it may be more beneficial to manage a stand of rice that averages as low as 60 plants m^{-2} rather than terminating the stand and replanting.

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